Loop-Dipole Antenna Modeling using the FEKO code

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ABSTRACT

A study was done to optimize the design of a loop dipole antenna over a broad frequency range (0.5- 2 GHz) using the FEKO method of moments code. Variations to the design were modeled as well as the performance of the antenna in an array. The modeling was compared to anechoic chamber data. The fields generated by the FEKO code were also input to a GTD (geometric theory of diffraction) code as an antenna pattern to model the multipath effects caused by mounting the antenna onto an aircraft.

I. Introduction and Technique

Loop dipole antennas operate over a broad frequency range and have patterns suitable for broad area coverage if mounted on the underside of an aircraft. Small changes to the antenna design (such as size and corrugation patterns) can be made to optimize the frequency coverage of the antenna. Using a C++ program to generate the input of the antenna to the FEKO method of moments (MOM) antenna code, the antenna design can be easily modified and quickly modeled to determine the effects. FEKO also allows for scaling factors to be added to the input fields, making antenna design changes easy to affect.

The fields generated by the FEKO code can also be input to the Ohio State BSC (Basic Scattering Code: Geometric Theory of Diffraction Code) as an antenna pattern to model the multipath effects caused by mounting the antenna onto an aircraft. FEKO also contains a hybrid method for integrating the MOM technique with a GTD technique, but this was not used on this project.

Two styles of loop dipoles were modeled, a simple non-corrugated (NC) loop dipole (Fig. 1), and a corrugated loop dipole (Fig. 2). The dielectric substrate (0.0003m thick) was also modeled as well as the leads to the antenna. For the corrugated model, the FEKO computation time for one frequency on a 2.8 GHz Pentium IV computer with 1 GByte of RAM for 0.05 λ segmentation (2,550 segments) was 80 sec. Segmentation sizes of 0.1 λ (800 elements, 5 seconds computation time) were sufficient for an accurate model of the antenna area (decreasing this gave little change in the results), with 0.025 λ needed for the leads. Up to ~11,000 elements were possible on this machine (9510 elements runs in 5 hours).

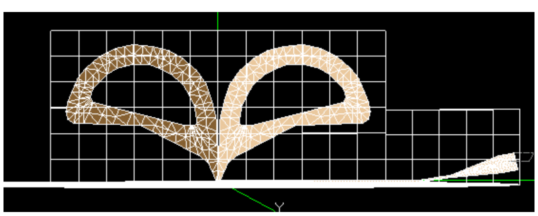

Fig. 1 FEKO model of Non-Corrugated (NC) Loop Dipole on a 1 ft. diameter groundplane

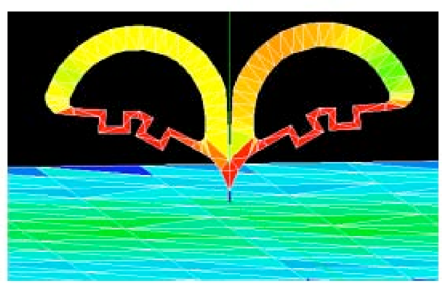

Fig. 2 Model of Corrugated Loop Dipole with currents (no dielectric)

II. One Element Modeling and Comparison to Chamber Data

Figs. 3-4 show the antennas mounted on a 1 ft. ground-plane, ready to be tested. Figs. 5-8 shows a comparison of the FEKO modeling versus anechoic chamber data for the two loop dipoles on a 1 ft. diameter circular groundplane (fed in the sum mode). A reasonable correlation was found, however, the experimental data showed lower gains, indicative of losses probably due to impedance mismatch (also seen as ripple when plotting gain over frequency, Fig. 9). Including the leads in the modeling had the effect of lowering the boresite gain by ~0.5 dB and reducing the

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bandwidth by about 0.2 GHz. The dielectric substrate had only a small effect on the results, mainly degrading the gain slightly for the frequency range above 1.2 GHz (ex. 0.4 dB at 1.8 GHz). Fig. 10 shows the antenna fed in the difference mode. Fig. 9 graphs the modeled and measured peak gains on boresite over frequency for the NC loop dipole fed in the sum mode.

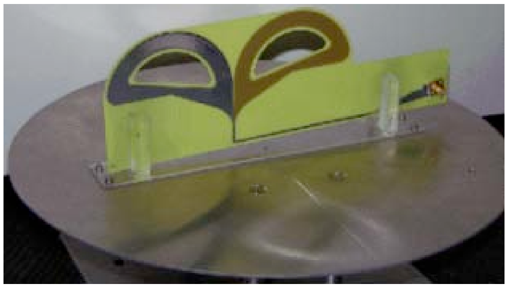

Fig. 3 NC Loop dipole antenna mounted on 1 ft. groundplane

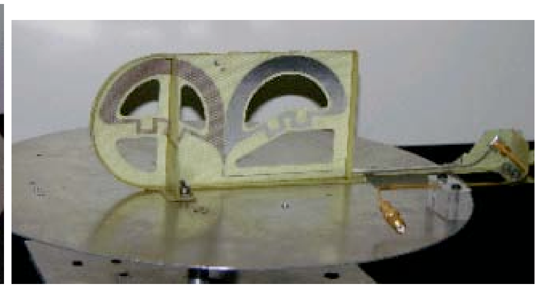

Fig. 4 Corrugated loop dipole antenna mounted on 1 ft. groundplane

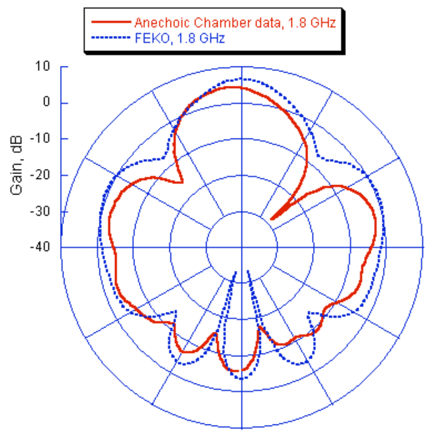

Fig. 5 Corrugated Loop Dipole Modeling: FEKO vs. exp. data at 1.8 GHz, E-plane cut cut

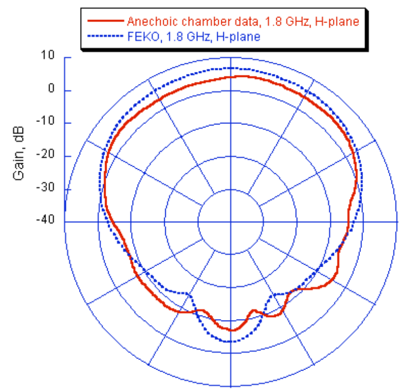

Fig. 6 Corrugated Loop Dipole Modeling: FEKO vs. exp. data at 1.8 GHz, H-plane

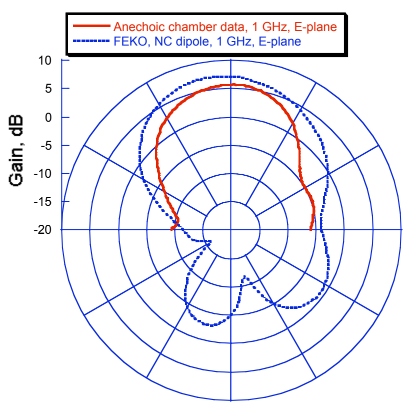

Fig. 7 NC Dipole w/ leads: FEKO vs. Exp. data at 1.0 GHz, E-plane cut

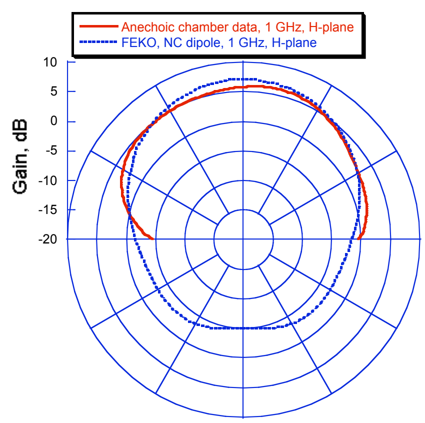

Fig. 8 NC Dipole w/ leads: FEKO vs. Exp. data at 1.0 GHz, H-plane cut

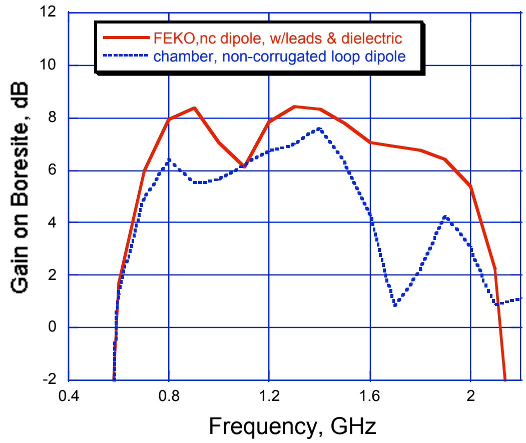

Fig. 9 Anechoic chamber data and FEKO at modeled peak gain over freq. for NC dipole

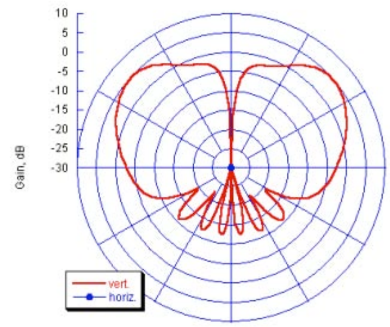

Fig. 10 NC Loop Dipole FEKO modeling 1.25 GHz, Difference configuration

The NC loop dipole design was scaled larger and smaller width-wise to determine if the frequency coverage could be improved. As shown in Fig. 11, decreasing the antenna width by a factor of 0.8 shifted the gain coverage higher by about 0.1 GHz. Increased the width by 1.2 improved the low and high band performance.

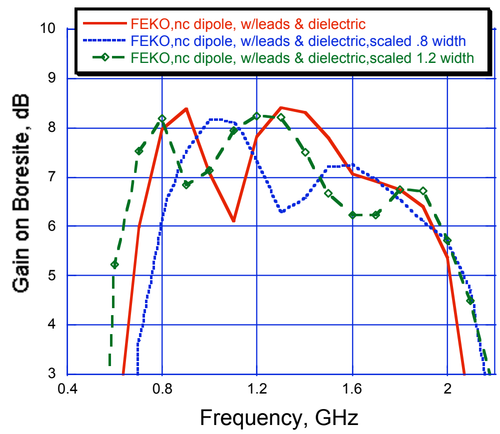

Fig. 11 FEKO peak gain on boresite for NC loop-dipole, w/ var. width-wise scaling

III. Array Modeling

The loop-dipole antenna was also modeled as an array, as shown in Fig. 12. The C++ pre-processing program was easily adapted to generate a set of dipole inputs for the FEKO code. (The FEKO code also has convenient options to replicate structures as well). Phasing can be adjusted to model beam pointing effects. Fig. 13 shows the array output with a phased input.

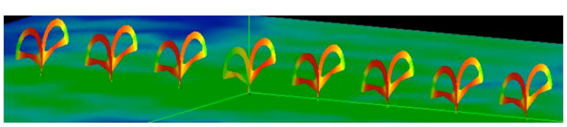

Fig. 12 Loop-dipole array modeling with FEKO

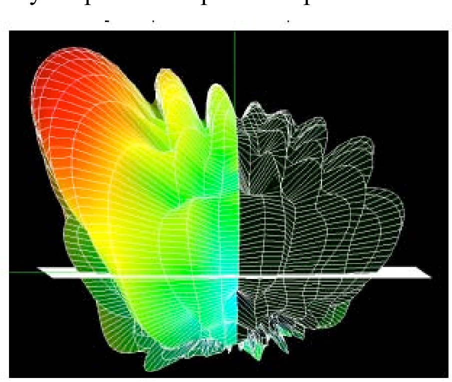

Fig. 13 Array output with phased input

IV. Simulations with Aircraft

The fields generated by the FEKO code can be inputted to the Ohio State BSC (Basic Scattering Code: Geometric Theory of Diffraction Code) as an antenna pattern to model the multipath effects caused by mounting the antenna onto an aircraft. Plates, cylinders, and cones were used to generate simplified models suitable for determining primary multipath effects. Figs. 14-16 show several aircraft models.

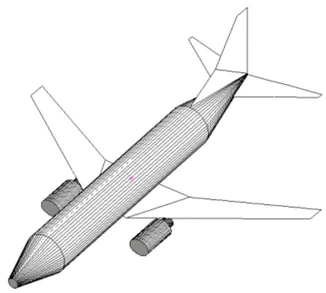

Fig. 14 Boeing 737

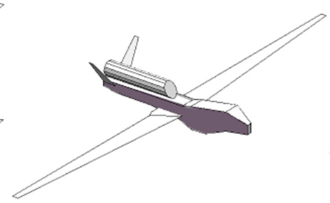

Fig. 15 Northrop Grumman Global Hawk

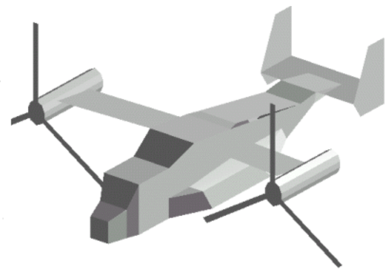

Fig. 16 V-22 Osprey

Fig. 17 shows the antenna pattern for the loop-dipole antenna alone and mounted beneath the Boeing 737 model. The aircraft increases the pattern ripple, primarily due to the multipath bounces off the antenna wings. The pattern deviations are worse, naturally, for the difference configuration because of the higher pattern gain near the aircraft structure.

A previously developed analysis technique can then be used to determine the multipath p-code error (which determines distance errors that would be seen by a GPS receiver due to the multipath) [1].

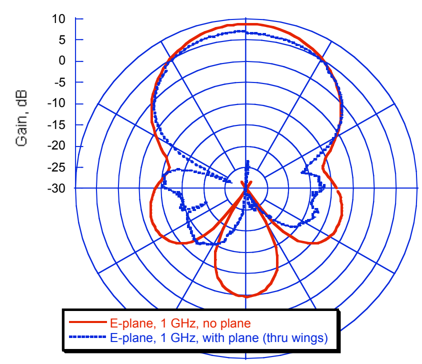

Fig. 17 BSC code modeling of loop-dipole on Boeing 737 with FEKO input, E-plane cuts (through wings)

V. Summary

The FEKO code proved an effective technique for accurately modeling a complex antenna. The graphical user interface (GUI) is powerful, intuitive, and easy to use. The processing speed is exceptional. Future work will involve modeling the feed structure more closely and correlating it with impedance measurements.

VI. References

[1] W. L. Lippincott, T. Milligan, D. Igli, "Method for Calculating Multipath Environment and Impact on GPS Receiver Solution Accuracy," Proceedings of the 1996 National Technical Meeting, ION-GPS January 22-24, 1996.

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